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Preliminary Note on the Position of the Liverpool Observatory.
By W. E. Plummer, M.A.

In the Annual Report of the Council for the year 1867 it is stated : "From five transits of *β Draconis*, four of *γ Draconis*, and one of *α Cygni*, each of them over the east and west prime verticals, the latitude (of the Liverpool Observatory) is 53° 24′ 3″·8 N." As far as I know, no details have ever been published, nor can I find in the archives of the Observatory any record of the observations.

It was with the view of confirming this result, and also to test how far the instrument was available for the accurate determination of latitude, that the following observations were undertaken.

The Observatory is not equipped with a transit circle, but a third pier has been erected to the north of the eastern pier at right angles to the meridian, and at such a distance as to permit the transit instrument being placed between this and the eastern pier. The Y bearings and the mounting generally are in all respects similar to those employed when the instrument is on the meridian. The new position of the line of collimation is 1 foot 8 inches north of the ordinary transit.

The means for reversal of the instrument are not convenient, and the operation cannot be effected under about three minutes, so that it is only for stars which cross within a few minutes of the zenith that it is possible to reverse the telescope during the transit. Practically the instrument has only been reversed for the determination of collimation, and the whole of the transit has usually been made in either the north or the south position. Neither could the telescope be used as a zenith instrument in the ordinary Talcott or Horrebow method. For these reasons it has been necessary to rely on pairs of observations of the same stars made on different nights in reversed positions of the axis.

It was originally intended to bisect the star when near the prime vertical by the micrometer wire, noting the time ; but this method had to be abandoned, not only because the micrometer was in a very inconvenient position for reading when the telescope was nearly vertical, but the earlier observations so made showed that there was some loss or irregularity in the screw which it was impossible to make entirely disappear. These observations have accordingly all been rejected, and those observations only have been retained which depend upon transits over the fixed wires of the instrument.

These are nine in number, and under the most favourable circumstances could only give four contacts in each reversed position of the instrument—another reason for not reversing during each transit. The intervals between these wires, when de-

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termined by means of the movable thread being brought into coincidence with each, exhibited the same uncertainty as that already noticed, and furnished additional grounds for the rejection of the earlier observations.

The wire intervals used depend entirely upon the meridional transits of polar stars, and are, I believe, perfectly trustworthy. The derivation of the intervals from the prime vertical observations themselves shows a satisfactory accord with those used.

The level corrections have always been small and consistent, and the practice has been to determine the level error at least three times in the course of the observations, practically about once an hour. There has been noticed an occasional tendency for the northern pier to sink (or the southern pier to rise) as the night wore on. The maximum effect has been to alter the level about 1″ in the course of the evening. The probable error of a single determination, however, is as much as 0″·2. It does not seem possible to connect this gradual change with temperature, since it is not always present, nor when the greatest range of temperature has been noticed. The value of the level scale 0″·90 is that which has been in use for some years. I have no adequate means of making a fresh determination. Practically, if ΔL be the correction to the level scale, the final latitude would have to be increased by 1·35 ΔL. An examination of the level errors as applied to separate values of the latitude in north and south positions of the instrument has not, however, shown the necessity of any correction.

The azimuth has remained small and constant throughout the observations. Sometimes stars at a considerable distance from the zenith have been observed, but it has been found sufficient to determine the hour angle of the meridian of the instrument from the zenith stars themselves. The correction $\frac{1}{2}a^2 \sin 1'' \cot \phi$ has never been sensible.

The transits have been made by the chronographic method. For slow-moving stars the method is probably inferior to eye and ear transits, but owing to the relative situation of the piers and the clock, the latter could not be seen when observing, and one was liable to errors in counting. The clock error and rates were so completely under control, that any error caused by their variation is of a smaller order than the error of observation.

Since there was no object in observing very close to the zenith, either with the view of reversing the telescope during the transit or from fear of irregularity in the performance of the clock, the choice of the selected stars depended upon the accuracy with which the transits could be made, and the effect of this error upon the latitude. If ϵ be the probable error in the time of transit, and t half the interval of time between E. and W. vertical circles, then the effect on the latitude ϕ is

$$d\phi = \frac{\epsilon}{2} \sin 2\phi \tan t.$$

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It was found that the probable error of observation was sensibly the same for all transits in which t exceeded 20°, and that, practically, the increase in the error of observation when t was less than 7° increased the error of the latitude. The minimum effect on the latitude was produced when t was about one hour or when $(\phi-\delta)$ was about one degree. As the effect of an error in the assumed declination of the star on the resulting latitude is expressed by

$$d\phi = d\delta \frac{\sin 2\phi}{\sin 2\delta},$$

possibly a slight increase in the accuracy might have resulted by making $\phi-\delta$ a larger angle; but this slight gain is more than compensated by the longer interval in the transit and the greater danger of losing the second by clouds.

On these considerations the following list of stars, arranged in order of $(\phi-\delta)$, was drawn up from the most authentic sources attainable. The declinations have been reduced as far as possible to the A. G. C. system, and the proper motions have in general been taken from the discussion of proper motion, vol. xxv. of the *Annals of the Harvard Observatory.* In a few cases the proper motion has been independently determined. The programme provided for observing each star five times in both north and south positions, and this rule has been very generally adhered to. The stars *c*, *f*, *l*, and *m* have, however, only been observed four times, the west transit being lost from clouds. An increase in the number of observations did not sensibly increase the accuracy of the result derived from each individual star, and of course the error in the assumed declination remained practically unremoved. It seemed more advantageous to increase the number of the stars than to multiply observations of the same star.

Letter of Reference.	Star's Name.	Assumed Declination. 1894·0. ° ′ ″	Assumed Proper Motion. ″	Approximate Right Ascension. 1894·0. h m s	Authority.
a	51 Draconis	53 14 2·25	+0·027	19 2 33·2	Gr. 80, Pulk. 55, Harv. 75.
b	κ Cygni	53 10 22·31	+ ·112	19 14 39·2	Berliner Jahrbuch 1894.
c	Groomb. 3408	53 7 49·74	+ ·006	21 6 58·9	Gr. 72, Pulk. 55, Gl. 70, Harv. 75.
d	Groomb. 2671	52 52 16·02	− ·034	18 44 25·2	Gr. 80, Rad. 45, Gr. 60, Harv. 75.
e	Groomb. 3383	52 51 49·21	·000	21 0 33·3	Gr. 80, Rad. 45, Wash. 60, Harv. 75.
f	Groomb. 3042	52 51 8·37	+ ·253	20 3 26·5	Gr. 72, Pulk. 55, Rad. 45, Harv. 75.
g	Groomb. 2699	52 50 20·14	+ ·352	18 49 12·7	Gr. 64, Pulk. 55, Wash. 60, Harv. 75.
h	Groomb. 3100	52 47 52·83	+ ·163	20 10 51·8	Rad. 45, Brus. 65, Harv. 75.
i	Groomb. 3690	52 47 21·76	− ·013	22 3 30·1	Wash. 60, Rad. 45, Harv. 75.
j	Groomb. 3617	52 44 24·58	·000	21 51 47·6	Gl. 70, Brus. 65, Rad. 45, Harv. 75.
k	20 Cygni	52 43 8·01	− ·132	19 47 58·1	Gr. 80, Pulk. 55, Rad. 45, Harv. 75.
l	Groomb. 3285	52 36 34·67	− ·100	20 43 16·9	Gl. 70, Brus. 65, Rad. 45, Harv. 75.
m	Groomb. 3434	52 36 33·75	− ·033	21 16 16·2	Rad. 45, Harv. 75.
n	Groomb. 3436	52 31 39·44	+ ·052	21 16 33·9	Rad. 45, Harv. 75 (double).
o	Groomb. 3480	52 29 29·33	+ ·031	21 26 48·6	Gr. 80, Pulk. 55, Rad. 45, Harv. 75.
p	Groomb. 3467	52 26 16·83	·000	21 23 15·3	Gr. 80, Rad. 60, 45, Brus. 65, Harv. 75.
q	ψ Cygni	52 9 26·75	− ·046	19 52 53·4	Berliner Jahrbuch, 1894.
r	Groomb. 2753	52 6 27·15	− ·010	18 59 37·5	Rad. 45, Harv. 75.
s	ι Cygni	52 6 15·87	− ·060	19 24 50·3	Gr. 72, Gr. 60, Rad. 45, Harv. 75.
t	Groomb. 3213	51 56 54·70	+ ·063	20 28 19·5	Rad. 45, Bonn 55, Harv. 75.
u	Lalande 40328	51 31 1·79	·000	20 45 30·8	Gr. 80, Brus. 65, Harv. 75.
v	Groomb. 3239	51 29 19·09	+ ·014	20 31 45·2	Gl. 70, Brus. 65, Rad. 45, Harv. 75.

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As an example of the agreement in the individual results determined from each of the two positions of the telescope, as well as to exhibit the constancy of the errors of the instrument, the latitude derived from the separate nights' observations of one star, the first in the list, is given. The collimation error has been determined both by reversion and by reflection. The level errors where a gradual change has been noticed as the night advanced have been varied with the time, the quantity shown in column 5 being that actually used; the azimuthal error has never been sufficiently large to be applied. In the final values for the latitude there remains only the correction due to the employment of inaccurate values in the intervals of the wires, and this is effectually masked by the errors of the observations themselves.

Date.		Position of Lamp.	$\phi'-\delta_a$	Error of Collimation Lamp N.	Inclination.	Azimuthal Error.	Appt. δ.	Latitude.
1894.			′ ″	″	″	″	° ′ ″	° ′ ″
Sept.	5	N.	9 48·24	+1·74	+2·62	−3·12	53 14 13·96	53 24 4·82
	6	S.	9 48·08	+2·03	+2·05	−3·05	14·12	4·25
	10	S.	9 48·97	+2·30	+0·41	−1·92	14·75	4·13
	13	N.	9 49·18	+1·60	+0·73	−1·47	15·15	5·06
	14	S.	9 48·68	+ ·42	+1·25	−0·73	15·28	5·20
	24	N.	9 45·32	+ ·27	+3·02	−1·25	16·31	4·65
	27	N.	9 43·94	− ·35	+3·87	−0·96	16·51	4·32
	29	S.	9 48·40	+ ·11	+0·26	−2·42	16·63	5·29
Oct.	1	S.	9 46·95	− ·86	+1·62	−3·80	16·73	5·30
	2	N.	9 47·77	−1·03	+0·83	−1·35	16·76	5·26

The mean results from each of the stars are as follows :—

Star.	Mean Latitude.	Average Deviation.	Star.	Mean Latitude.	Average Deviation.
	° ′ ″	″		° ′ ″	″
a	53 24 4·83	0·40	*l*	53 24 5·63	0·39
b	5·25	0·53	*m*	5·22	0·56
c	5·04	0·36	*n*	4·39	0·75
d	4·27	0·62	*o*	4·70	0·32
e	4·64	0·44	*p*	4·28	0·41
f	4·32	0·53	*q*	5·44	0·38
g	4·98	0·39	*r*	5·04	0·83
h	5·45	0·70	*s*	4·31	0·36
i	5·21	0·63	*t*	5·29	0·42
j	3·97	0·75	*u*	4·70	0·55
k	4·26	0·58	*v*	5·04	0·70

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The average deviation of each determination from the mean is given, from which the probable errors could easily be derived; but the uncertainty in the assumed declination of the star remains, though it is hoped that to some extent its influence on the final result is removed by employing a considerable number of stars. In presence of this uncertainty, however, it does not seem desirable to adopt any more elaborate method of deducing the mean result than to take the arithmetic mean, and this gives for the latitude of the Liverpool Observatory 1894·7 53° 24′ 4″·84.

An examination of the residuals discloses the unwelcome fact that they are rather large, and that the further prosecution of the subject with the present instrument is not likely to be of any scientific value as a contribution to the question of the variation of the latitude.

Longitude.

The information concerning the longitude determination is as vague as that of the latitude. In the Report of the Council, 1868, already quoted, it is stated that the difference of longitude between the old and the new observatory was "found by the transmission of sixty chronometers to be $17^{s}·04$." The longitude of the old observatory was determined by the late Astronomer Royal in the course of the Valentia inquiry (1844), and is quoted for several years in the *Nautical Almanac* as $12^{m}\ 0^{s}·11$ W.

So far as can be gathered from the records, these sixty chronometers were simply carried from one observatory to the other in the ordinary course of removal, no repetition of the journey being made. Consequently any error in the original determination of clock error impressed itself on the result. Circumstances pointed to the fact that these errors might be considerable, both in the last clock error in the old observatory, and in the first in the new. Further, the longitude of the old observatory rested entirely on the results of the chronometrical expedition in 1844, and might very well be repeated by the method of galvanic signals. It is true that the 1862 determination of the Feagh Main Station by this process agreed very closely with the older result, so that no considerable alteration in the assumed longitude of the new observatory could be anticipated, but the connecting link between the two seemed sufficiently weak to make a fresh inquiry desirable.

The method employed was the exchange of signals recorded on the respective chronographs of the two observatories, the clock errors being determined at each observatory in the ordinary course of observation. The hour chosen for the exchange of signals was 9 P.M., a time when, weather permitting, observations were usually going on, and any uncertainty in the clock rate was practically avoided. The clock employed here was the Bond clock, mentioned in the Report of the Council, 1868. It has

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always given me most trustworthy results. The Astronomer Royal has kindly furnished me with the clock errors and rates of the sidereal standard employed at Greenwich.

With regard to the Liverpool observations, it may be mentioned that the collimation error has been determined both by observations of the reflected wire and by transits of polar stars in reversed positions of the intrument. The agreement between the two methods is not very satisfactory, though the difference is by no means systematic. The want of stability in the screw mentioned in the case of the latitude observations is the probable cause of the disagreement, and, as a matter of fact, the collimation error rests entirely on the observation of polar stars. The variation of the error from night to night is very small, and it is believed that the error itself is accurately known. The level error has been found by means of a striding level, and the remarks on the determination of its scale referred to in the earlier sections are to be considered here. The results of the prime vertical observations have, on the whole, convinced me of the very approximate accuracy of the scale value. The level error has also been derived from reflection; but here, again, the method has never recommended itself. The azimuthal error has been derived from the observation of the ordinary polar stars, including those whose places are given in the *Connaissance des Temps.* Within the period embraced by the longitude observations, seven stars were used.

Owing to some difficulty in making the proper connections with the Liverpool chronograph, the Greenwich signals failed to register for the first few nights, and not all the signals (thirty from each station) sent from Liverpool were registered at Greenwich. The "relay time" (shown below), however, seems sufficiently well known from the latter part of the inquiry to warrant the application of one-half the mean interval to the earlier observations.

	Relay Time. Mean of 20 Signals.	Relay Time. Mean of 10 Signals.
	s	
Aug. 30	(−0·003) (only 8 recorded)	
		s
Sept. 4	+ ·016	+0·024
5	+ ·020	+0·035
6	+ ·006	+0·038
12	+ ·025	+0·032
13	+ ·017	+0·049
19	+ ·027	+0·022
20	+ ·015	+0·010
26	+ ·024	+0·039
Mean	+ ·019	+0·031

The mean 0s·023 has been assumed as the correct interval on those days on which the signals were not efficiently exchanged.

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Two attempts were made to determine the personal equation of the Liverpool observer, referred to the Greenwich standard. The results are not very satisfactory. Bad weather defeated the earlier attempt, the only result being to show that the personal equation was practically zero. At the second attempt the following, not very accordant results, were obtained :—

Date.	Greenwich—Liverpool (Clock Slow).	Date.	Greenwich—Liverpool (Clock Slow).
	s		s
1894 April 21	+0·33	1894 April 28	0·00
26	−0·10	May 1	+0·14
27	+0·17		

The mean $+0^{\mathrm{s}}{\cdot}11$ has been employed in the derivation of the following values of the longitude from each of the nights on which signals were satisfactorily exchanged :—

		m	s			m	s
1893 Aug. 9	Long. W.	12	17·34	1893 Sept. 6	Long. W.	12	17·27
15			17·24	12			17·33
16			17·24	13			17·42
23			17·36	19			17·39
30			17·30	20			17·34
Sept. 4			17·38	26			17·33
5			17·37				

The mean of these values it is proposed to adopt for the present, and the resulting position of the Liverpool Observatory is—Latitude, N. 53° 24′ 4″·8 ; Longitude, W. $12^{\mathrm{m}}\ 17^{\mathrm{s}}{\cdot}33$.

Liverpool Observatory,
1894 *November* 8.

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Observations of Comet II. 1894 (*Gale*). By W. E. Plummer, M.A.

The following observations of Gale's Comet have been made with the equatorial of the Liverpool Observatory. When the comet was sufficiently bright to admit of any illumination in the field the observations were made with a filar micrometer. The remainder, marked "Ret.," have been made by a micrometer of thick wires crossed at right angles, and placed at an angle of 45° with the meridian. Five transits have usually been made when this micrometer has been used. All the observations have been corrected for differences of refraction, but no corrections for parallax have been applied. In the column "Observer," the letters "P." and "S." refer to Mr. Plummer and Mr. Skinner, respectively :—

Liverpool Mean Time of Observation.		☄ − ✱ R.A.	No. of Comparisons (α).	Apparent R.A. of ☄.	☄ − ✱ Declination.	No. of Comparisons (δ).	Apparent Declination of ☄.	Log Factor of Parallax in (α).	Log Factor of Parallax in (δ).	Observer.	Star of Reference.
1894.	h m s	m s		h m s	′ ″		° ′ ″				
May 4	8 37 2	+8 58·51	13	8 28 17·01	+10 9·7	3	− 3 14 19·6	9·3966	0·8617	P.	*a*
	...	+7 53·97	13	8 28 16·30	+19 25·1	3	− 3 14 16·4	...	...	P.	*b*
7	9 34 11	+ 22·60	16	8 27 59·99	+15 58·5	4	+ 7 29 58·3	9·4629	0·8204	P.	*c*
9	10 2 58	+1 0·02	16	9 15 2·56	+ 1 5·5	4	+13 23 19·5	9·4952	0·7966	P.	*d*
	...	− 29·66	16	9 15 2·64	−10 33·0	4	+13 23 17·4	...	...	P.	*e*
10	9 53 37	− 49·33	12	9 22 44·36	+ 5 17·4	3	+15 55 24·2	9·4846	0·7781	P.	*f*
	10 7 49	− 44·84	12	9 22 48·85	+ 6 44·9	3	+15 56 51·7	9·5013	0·7883	S.	*f*
12	11 13 46	+ 39·21	16	9 37 19·20	+ 1 14·7	4	+20 28 18·3	9·5600	0·7883	P.	*g*
	11 20 47	− 6·26	12	9 37 21·32	−11 47·1	3	+20 28 55·0	9·5634	0·7922	P.	*h*
16	10 35 22	+1 44·19	16	10 1 14·16	+ 4 57·0	4	+27 5 20·7	9·5480	0·7168	P.	*i*
	...	− 37·88	16	10 1 14·52	− 5 52·9	4	+27 5 21·3	...	...	P.	*j*